

A GLOBAL WATER BUDGET ASSESSMENT

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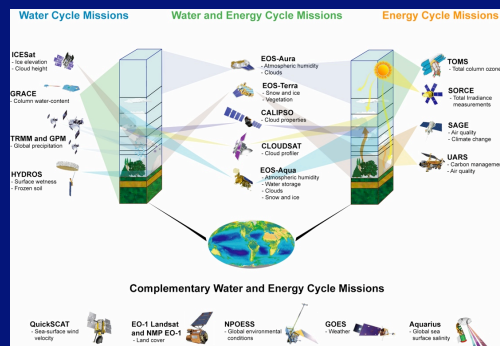
Joint Program on the Science and Policy of Global Change
(JP Tech. Report #179, and accepted with minor revisions to J. of Hydrometeorology)

Acknowledgements:

Global Soil Wetness Project Phase 2 (GSWP-2) Model Participants as well as
Paul Dirmeyer (COLA) and Taikan Oki (U. of Tokyo)

Chung-Lin Shie (GSSTF2b)

Bob Adler, George Huffman and Co. for GPCPV2.1



NEWS PI Meeting, Dec. 2-3, 2009



“Modern-Era” Global Assessment

UNITS KG/YR	PRECIPITATION	EVAPORATION	P-E
LAND	1.05E+17 ± 0.02E+17	GOLD1: 0.64E+17	~4.0E+16
	1.02E+17 ± 0.02E+17	GOLD2: 0.62E+17	~4.2E+16
OCEAN	3.80E+17 ± 0.06E+17	4.41E+17	6.50E+16
	3.72E+17 ± 0.04E+17	3.93E+17	1.70E+16
GLOBAL	GPCP 4.85E+17 ± 0.06E+17	GSSTF2+GOLD 5.03E+17	~ 2.4E+16
	CMAP 4.74E+17 ± 0.04E+17	HOAPS+GOLD 4.56E+17	~ 2.4E+16

from Schlosser and Houser, 2007

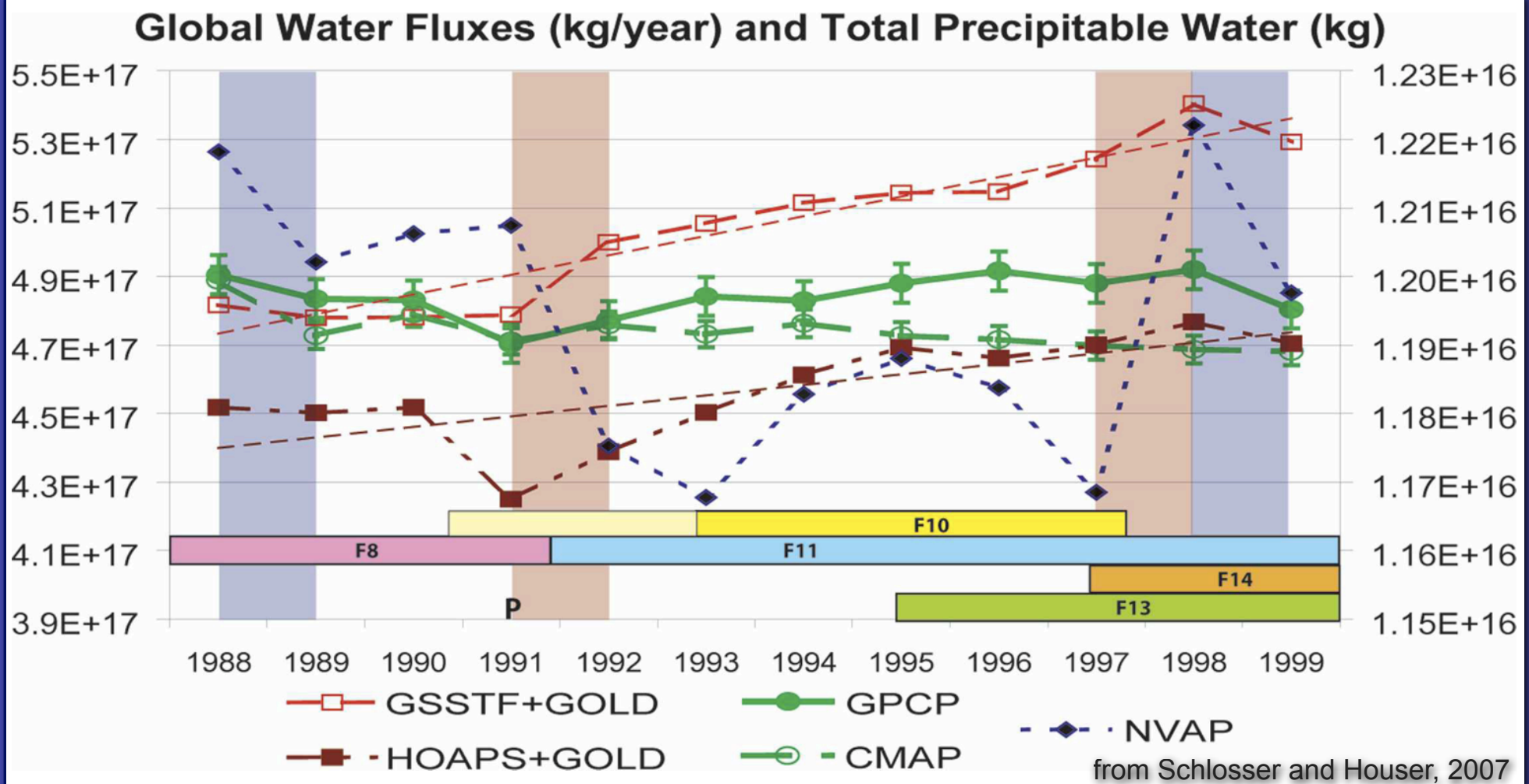
- **GLOBAL ANNUAL MEAN PRECIPITATION AND EVAPORATION BALANCE TO ~5%.**
- **DOES UNCERTAINTY IN GLOBAL LAND EVAPOTRANSPIRATION HELP OR HINDER?**



NEWS PI Meeting, Dec. 2-3, 2009



“Modern Era” Annual Budget

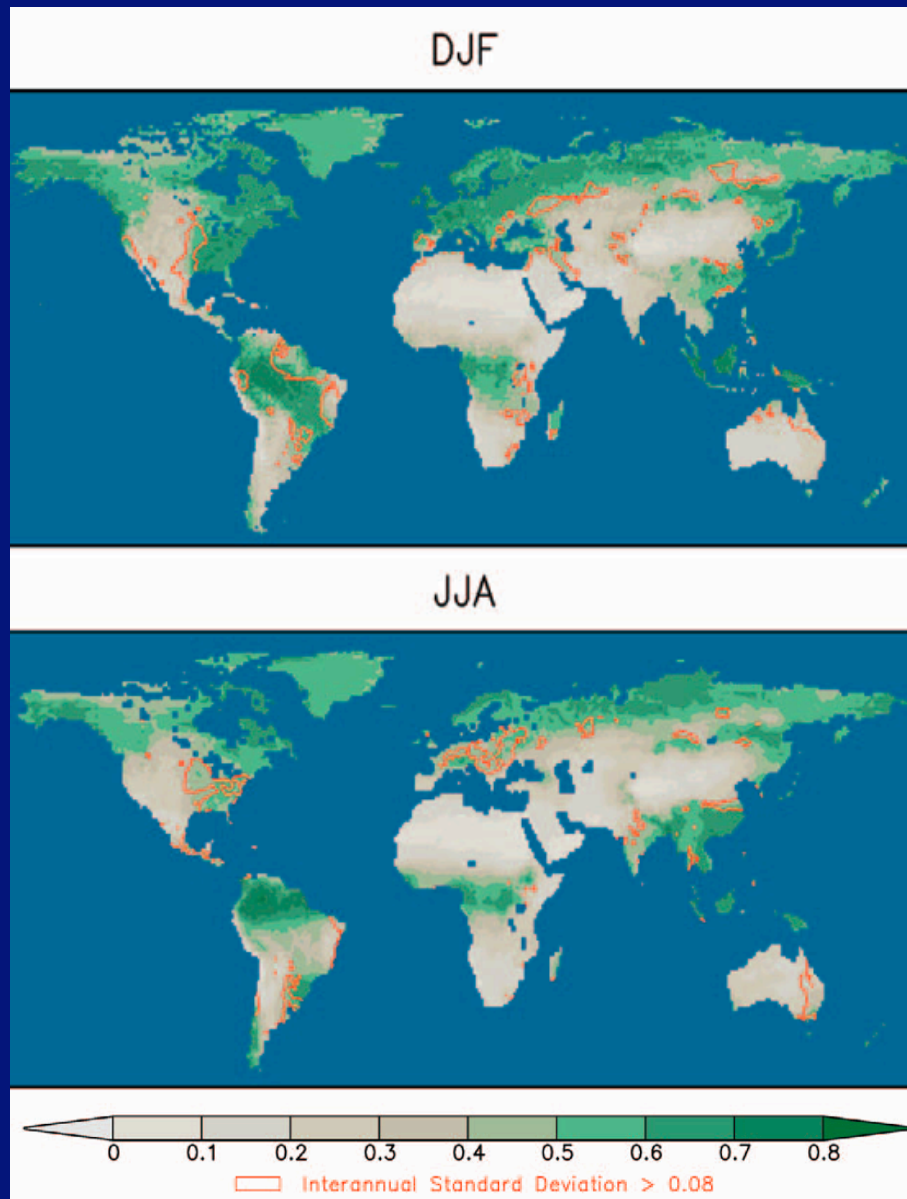


Can confidence in our estimates of land evapotranspiration constrain this budget?

NEWS PI Meeting, Dec. 2-3, 2009

The Second Global Soil Wetness Project (GSWP-2)

(DIRMEYER ET AL., 2006, BAMS)



AN ENVIRONMENTAL MODELING RESEARCH ACTIVITY TO COMPARE AND EVALUATE 10-YEAR (1986-1995) SIMULATIONS OF GLOBAL SURFACE STATE VARIABLES AND FLUXES BY A BROAD RANGE OF LAND SURFACE MODELS UNDER CONTROLLED CONDITIONS (EXTERNALLY SPECIFIED SURFACE FORCINGS AND STANDARDIZED SOIL AND VEGETATION DISTRIBUTIONS).

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GSWP-2 Participating Models

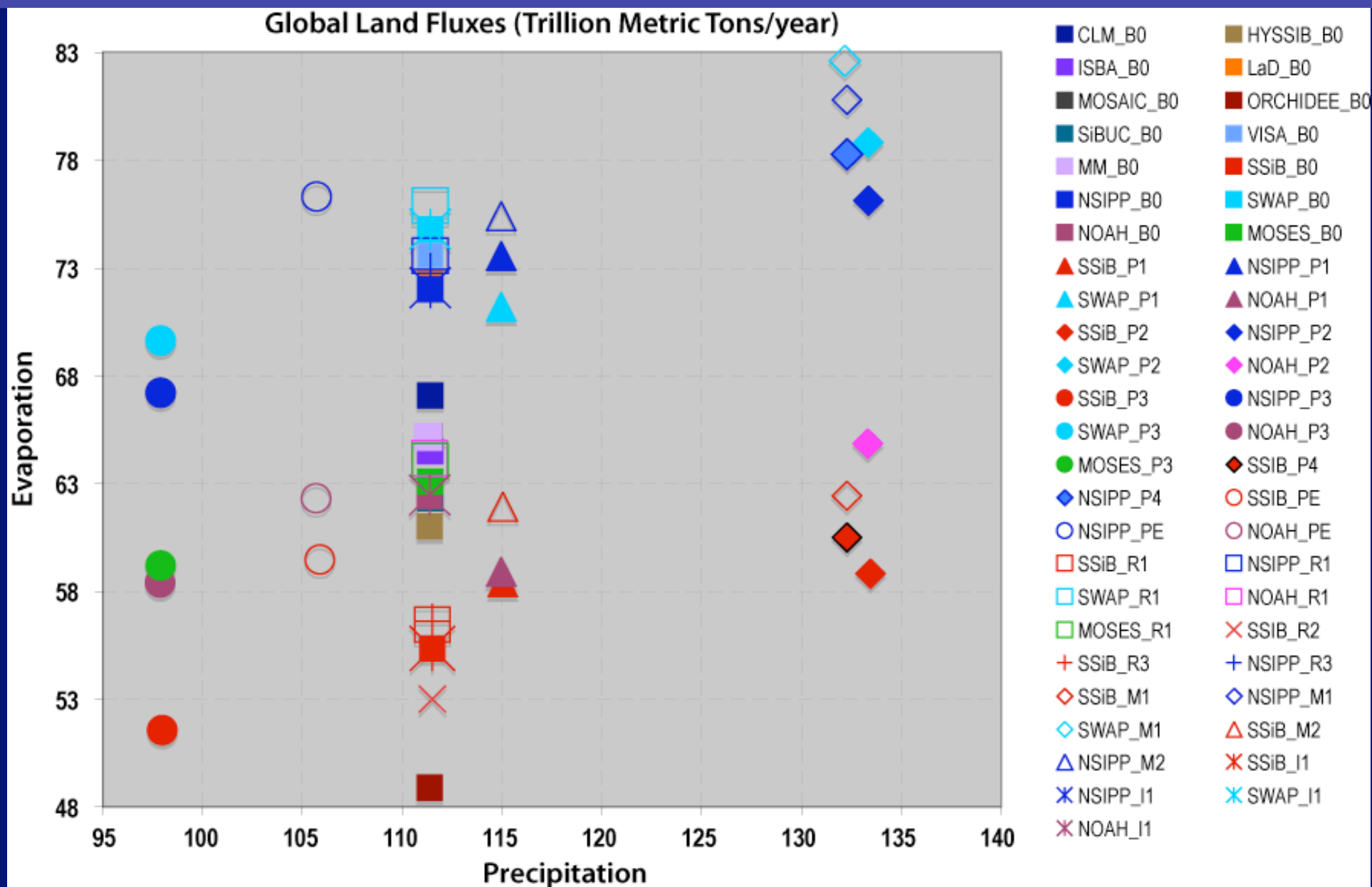
Name	Institute	Nation	Time step	Vertical Structure ¹
CLM2-TOP	U. Texas	USA	1hE 5mS ²	10W 10T 5S
HY-SSiB	GSFC	USA	30m	3W 2T 2S
ISBA	Météo France / CNRM	France	5m	3W 2T 1S
Mosaic	NASA / GSFC / HSB	USA	30m	3W 2T 1S
MOSES2	Met Office	UK	30m	4W 4T 1S
NOAH	NOAA / NCEP / EMC	USA	15m	4W 4T 1S
NSIPP-Catchment	NASA / GSFC / GMAO	USA	20m	3W 6T 3S
SiBUC	Kyoto U.	Japan	1h	3W 2T 1S
SSiBCOLA	IGES / COLA	USA	30m	6W 6T 1S
SWAP	Russian Academy of Sciences / IWP	Russia	3h	2W 1T 1S
VISA	U. Texas	USA	3hE 5mS ²	10W 10T 5S
LaD	NOAA / GFDL	USA	30m	1W 18T 1S
ORCHIDEE	IPSL	France	1h	4W 7T 1S
Sland	U. Maryland	USA	20m	1W 2T 0S
BucketIIS	U. Tokyo	Japan	3h	1W 1T 1S

LAND MODELS ARE USED IN GLOBAL CLIMATE AND
WEATHER MODELS FOR RESEARCH AND PREDICTION

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GSWP-2 Simulation Experiments

Exp	Description
B0	Baseline integration (NCEP/DOE with hybrid: temperature = CRU, precipitation = GPCC, gauge corrected, GPCP supplement; radiation=SRB)
P1	ERA-40 precipitation (no observational data)
PE	Hybrid ERA-40 precipitation (instead of NCEP/DOE)
P2	NCEP/DOE hybrid with GPCC corrected for gauge undercatch (no satellite data)
P3	NCEP/DOE hybrid with GPCC (no undercatch correction)
P4	NCEP/DOE precipitation (no observational data)
R1	NCEP/DOE radiation
R2	ERA-40 radiation
R3	ISCCP radiation
M1	All NCEP meteorological data (no hybridization with observational data)
M2	All ECMWF meteorological data (no hybridization with observational data)
I1	Climatological vegetation



MODEL RANGE IS LARGER THAN SENSITIVITY TO UNCERTAINTY IN THE ATMOSPHERIC FORCINGS (I.E. PRECIPITATION AND RADIATION).

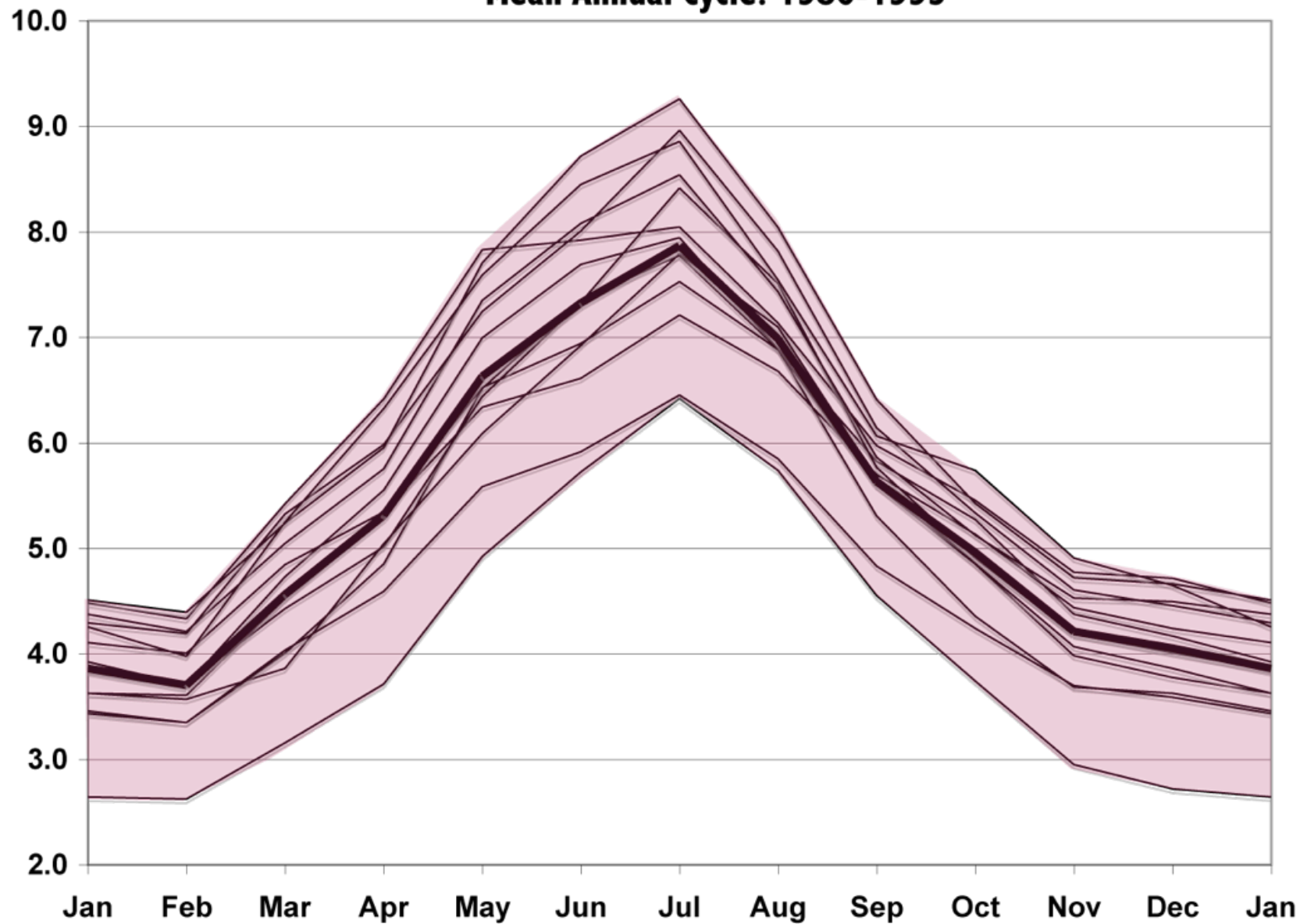
CONSISTENCY OF IMPLIED GLOBAL OCEAN EVAPORATION

Land Evaporation		Global Precipitation	
Antarctica	GSWP-2	GPCP	CMAP
7.41E+14	6.51±0.08E+16	4.9±0.15E+17	4.94±0.09E+17
Ocean Evaporation			
GPCP – GSWP-2*	CMAP – GSWP-2*	HOAPS3	GSSTF2
4.24±0.15E+17	4.28±0.09E+17	3.95E+17	4.30E+17

Units in kg/year

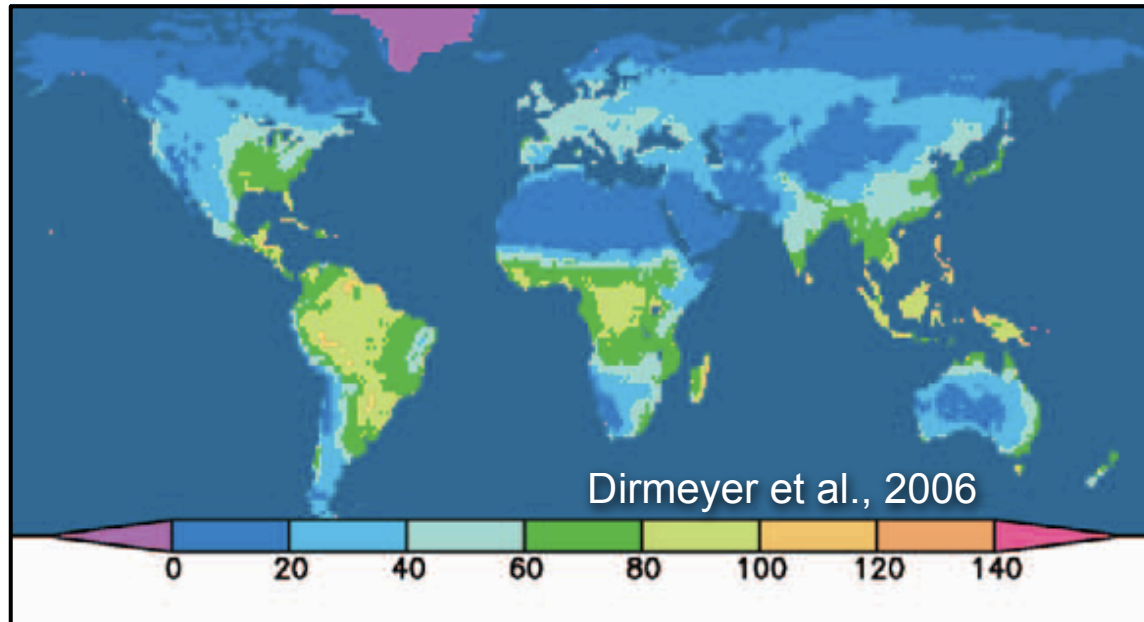
RESIDUAL OF GLOBAL PRECIPITATION AND LAND EVAPORATION
(GSWP-2 PLUS ANTARCTICA) FALLS WITHIN INDEPENDENT
ESTIMATES OF GLOBAL OCEAN EVAPORATION.

Global Land Evaporation from GSWP-2 Models (TMT/month)
Mean Annual Cycle: 1986-1995

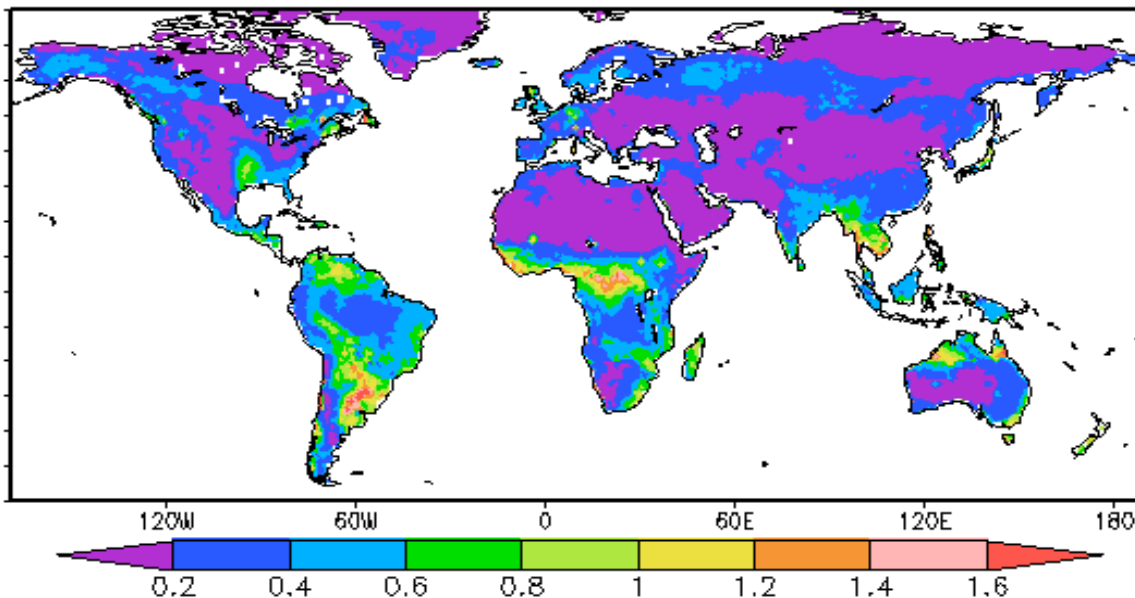


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GSWP-2 Annual Latent Heat Flux (W/m^2) Baseline Simulations
Multi-Mean Model Mean



Standard Deviation (mm/day) of GSWP-2 Evapotranspiration
Baseline Simulations

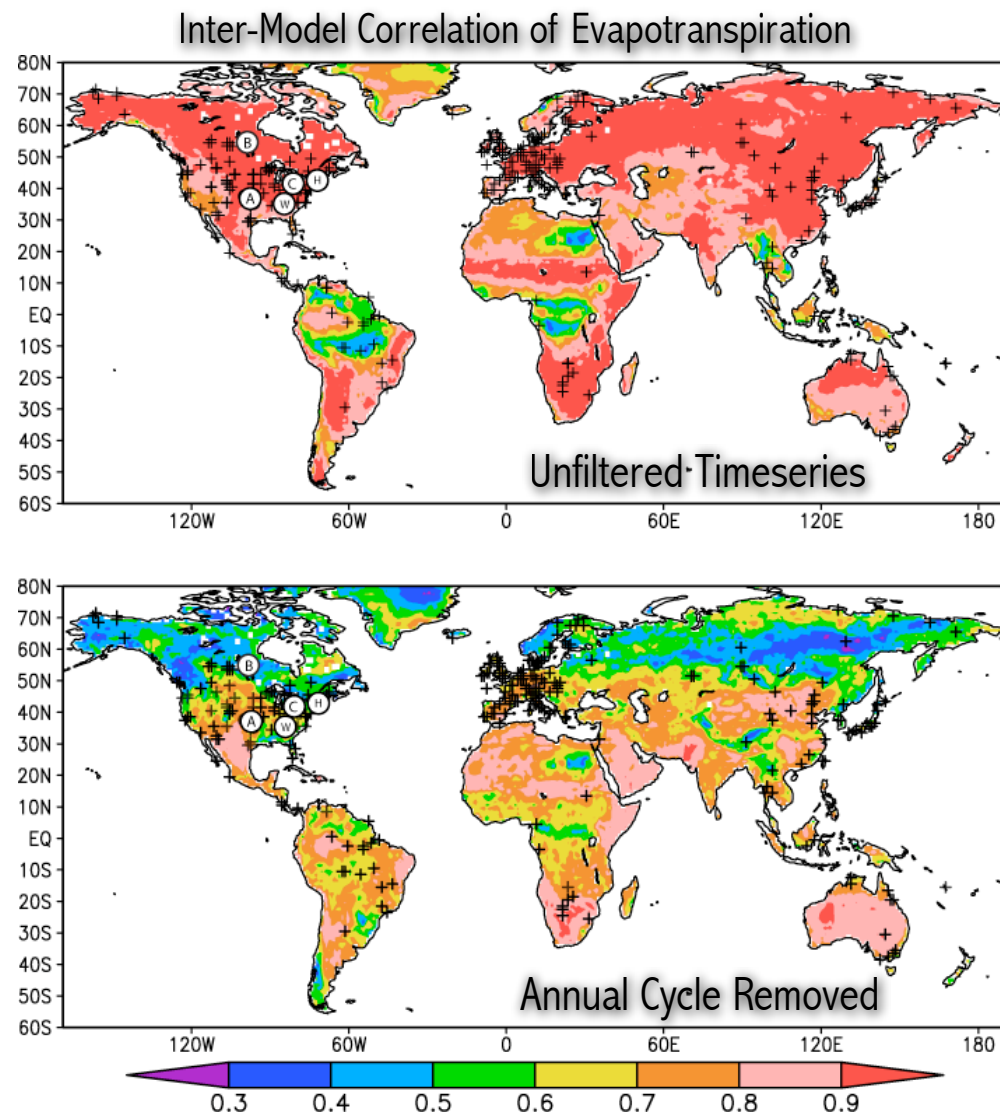


AREAS OF
PROMINENT SCATTER
IN TROPICS AND
NORTHERN HIGH
LATITUDES

SOURCES OF MODEL
INCONSISTENCY:
SEASONAL? AND/OR
INTER-ANNUAL?

Consistency in Evapotranspiration

Results from Global Soil Wetness Project Phase 2 (GSWP-2)



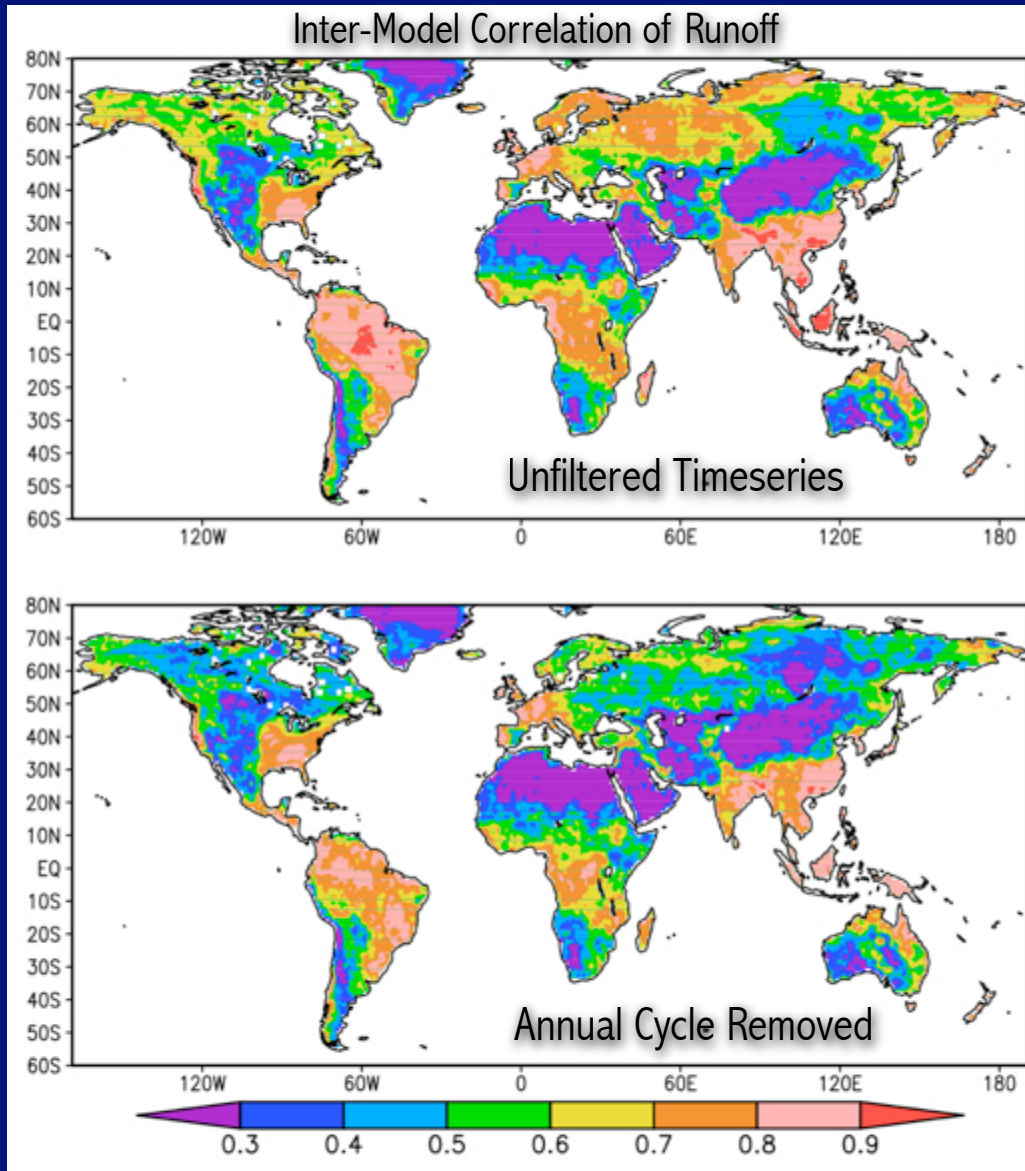
Schlosser and Gao, 2009

SCATTER (I.E. RMS DIFFERENCES AMONGST MODELS) RESULT OF SEASONAL INCONSISTENCIES IN TROPICS AND INCONSISTENCIES OF INTERANNUAL VARIATIONS AT HIGH (NORTHERN) LATITUDES.

LOCATIONS OF MOST SIGNIFICANT MODEL INCONSISTENCIES WITH LOW DENSITY OF STATION DATA.

Consistency in Runoff Simulations

Global Soil Wetness Project Phase 2 (GSWP-2)



SIMILAR TO EVAPOTRANSPIRATION, A DECAY IN CONSENSUS AMONG THE MODELS IN THE INTER-ANNUAL VARIATIONS OF RUNOFF AT HIGH LATITUDES IS FOUND.

ALSO “AGREEMENT” IN THIS IMPORTANT HYDROLOGIC FLUX IS NOT AS ROBUST AS COMPARED TO EVAPOTRANSPIRATION.

DATA SYNTHESIS

PRECIPITATION (1979-1999):

- GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP): ADLER ET AL., (2003)
 - VERSIONS 2.0 AND 2.1
- CPC MERGED ANALYSIS OF PRECIPITATION (CMAP): XIE AND ARKIN (1997)

OCEAN EVAPORATION (1987-1999):

- GODDARD SATELLITE-BASED SURFACE TURBULENT FLUXES VERSION 2
 - GSSTF2: CHOU ET AL., (2003)
 - GSSTF2B: CHUNG-LIN SHIE, PERSONAL COMMUNICATION
- HAMBURG OCEAN ATMOSPHERE PARAMETERS AND FLUXES FROM SATELLITES
 - HOAPS-G: BENTAMY ET AL. (2003) AND FAIRALL ET AL. (1996)
 - VERSIONS 2.0 AND 3.0

LAND EVAPORATION:

- GLOBAL SOIL WETNESS PROJECT PHASE 2 (GSWP2): 1986-1995
 - 13 GLOBAL LAND MODELS FORCED WITH ISLSCP II DATA AT 1° RESOLUTION

PRECIPITABLE WATER (1988 - NEAR PRESENT):

- NASA GLOBAL WATER VAPOR PROJECT (NVAP): VONDER HARR ET AL. (2003)
- AIRS/AMSR-E: E. FETZER AND NEWS COLLABORATORS

Atmospheric Budget:

$$dQ / dt = E - P - \text{div}(Q_t)$$

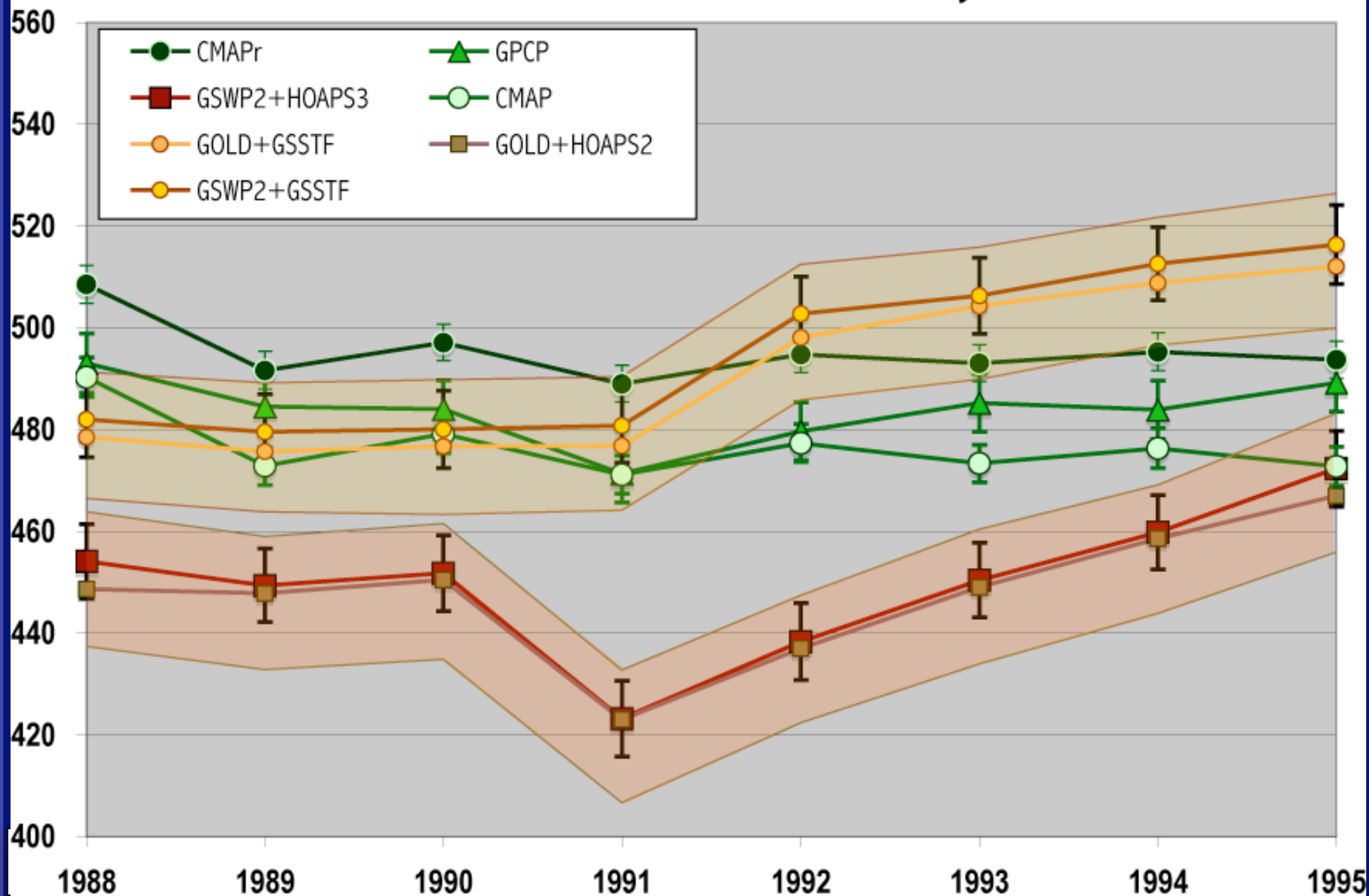
for global-scale analysis,
 $\text{Div}(Q_t) \sim 0$ and

$$dQ / dt = E - P$$



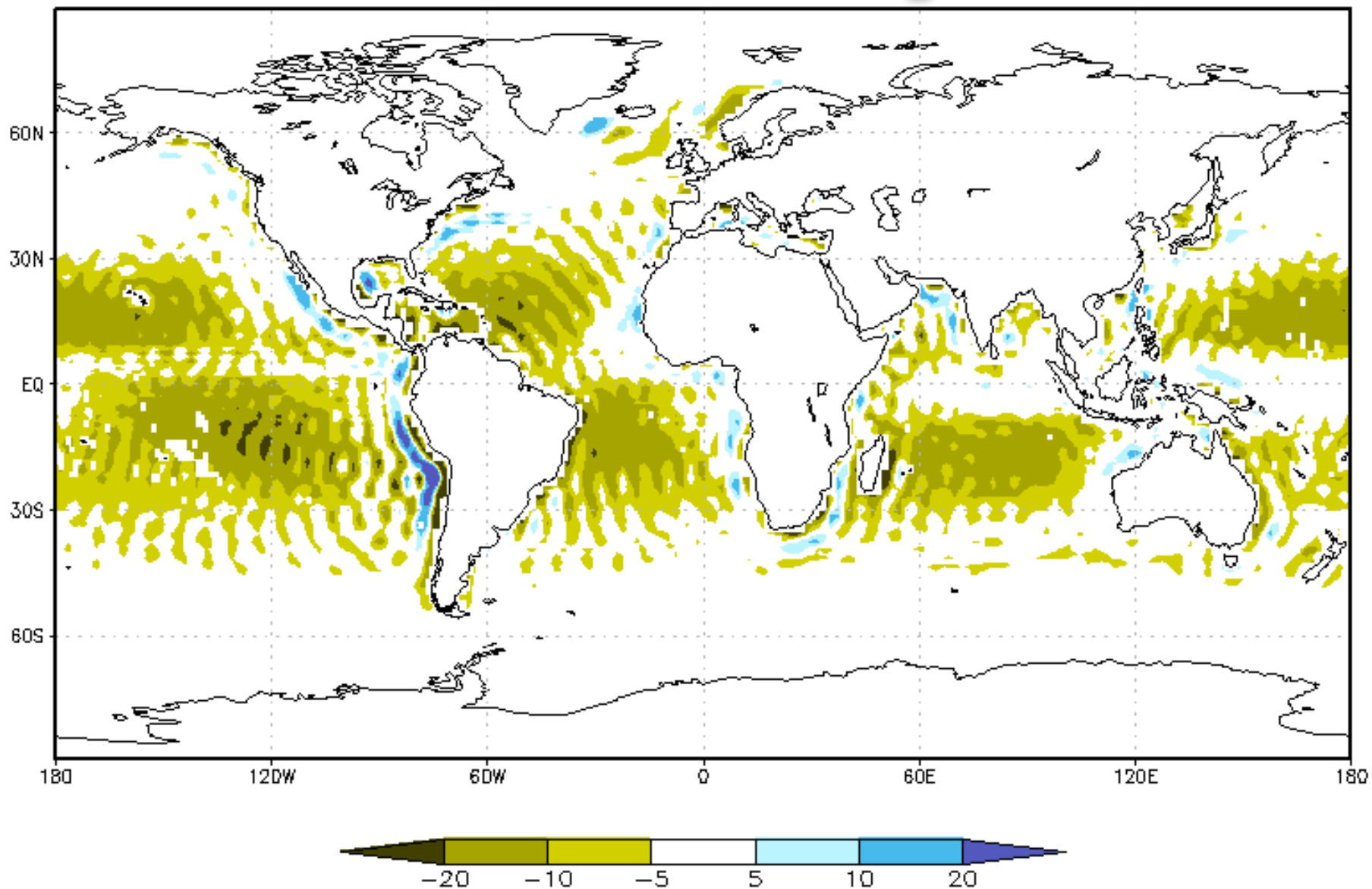
Balance & Consistency of Global Annual Fluxes

Global Annual Water Fluxes (TMT/year)



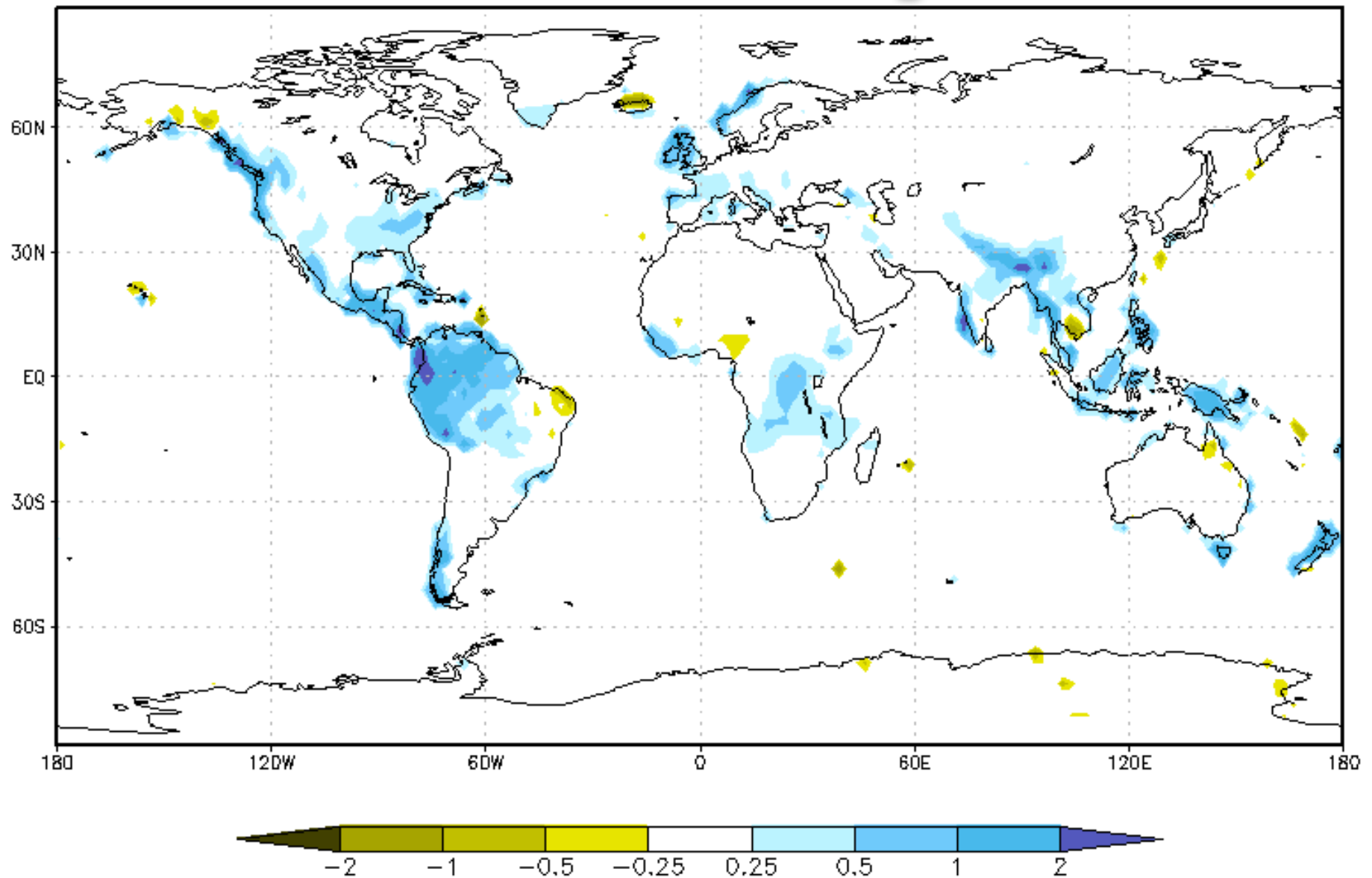
GSSTF2b - GSSTF2 (W/m^2)

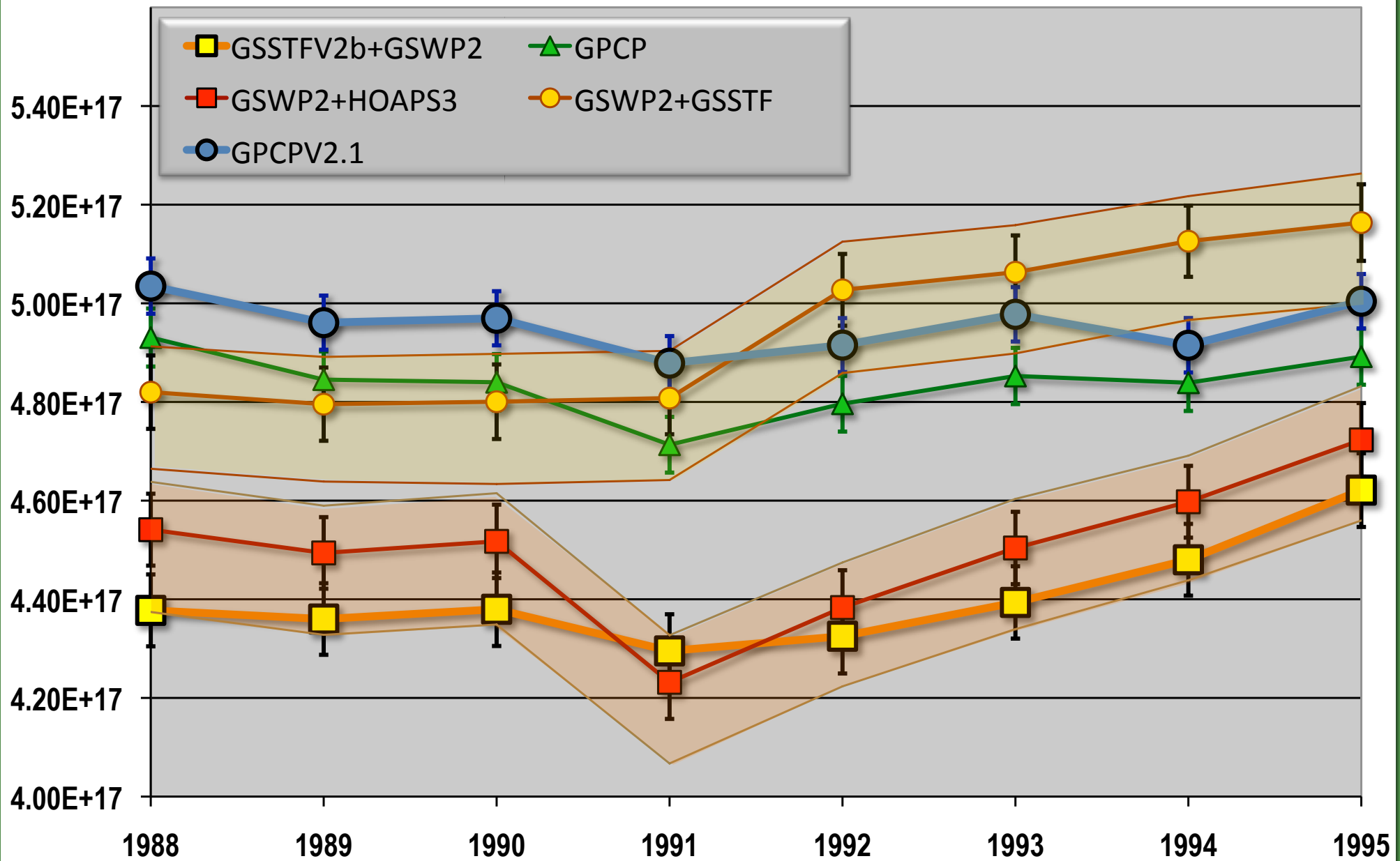
1988-1999 Averages



GPCP2.1 - GPCP2.0 (mm/day)

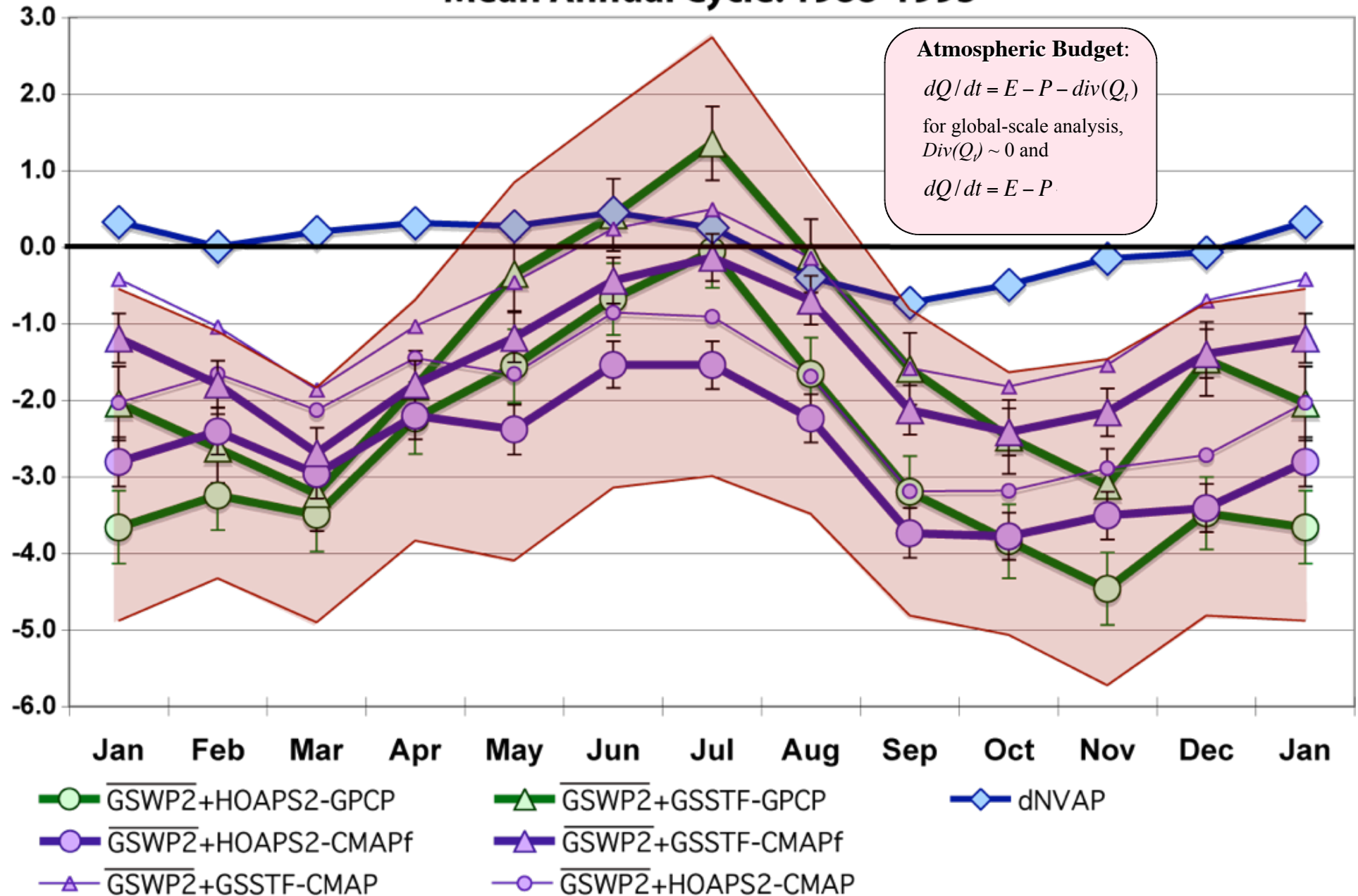
1988-1999 Averages





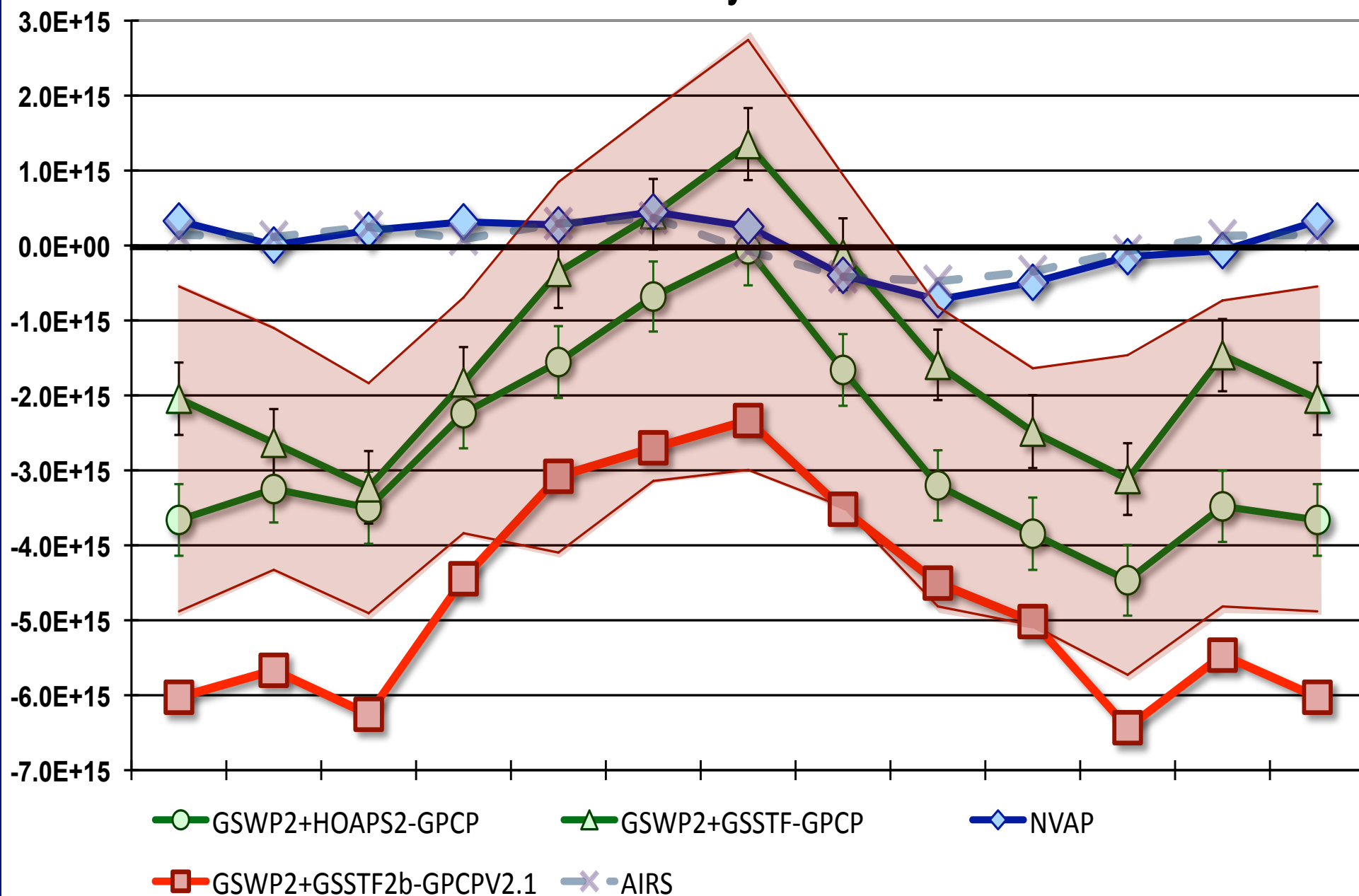
Global E-P Fluxes and Atmospheric Storage Change (TMT/month)

Mean Annual Cycle: 1988-1995



Global E-P Fluxes and Atmospheric Storage Change (kg/month)

Mean Annual Cycle: 1988-1999



CLOSING REMARKS

- GSWP-2 EVAPOTRANSPIRATION ESTIMATES CONSTRAIN A MODERN-ERA GLOBAL WATER BUDGET TO WITHIN $\pm 2.5\%$, BUT CANNOT EXPLAIN THE IMBALANCE. INCONSISTENCIES IN SEASONAL VARIATIONS SEEN.
- INTER-MODEL TEMPORAL INCONSISTENCIES ARE LARGEST FOR (NORTHERN) HIGH LATITUDE INTER-ANNUAL VARIATIONS AS WELL AS FOR THE INTER-SEASONAL VARIATIONS IN THE TROPICS.
- LARGEST IMPROVEMENTS IN MODEL-BASED ESTIMATES WILL BE DELIVERED THROUGH REFINEMENTS IN THE NUMERICAL RECIPES - NOT IMPROVEMENTS IN ATMOSPHERIC FORCING.
- VARIATIONS OF ATMOSPHERIC STORAGE ARE ROUGHLY 0.01% OF GLOBAL PRECIPITATION OR EVAPORATION. THUS, THE SCATTER OF THE GSWP-2 EVAPOTRANSPIRATION (2.5%) SEEMS QUITE UNSATISFACTORY. HOWEVER - RIGOROUS ERROR ESTIMATES IN WATER VAPOR RETRIEVALS REMAIN ELUSIVE.
- EMPHASIS TO IMPROVE HIGH-LATITUDE (COLD-SEASON) PROCESSES, AS LOW DENSITY OF DATA EXISTS. FUTURE FIELD EXPERIMENTS NEED TO AUGMENT THE LOW DATA-DENSITY AREAS, AND MUST SATISFY MULTITUDE OF OBSERVATIONAL REQUIREMENTS SPANNING BIOGEOPHYSICAL AND BIOGEOCHEMICAL PROCESSES:
 - CARBON CYCLING AND THE BIOGEOCHEMISTRY OF PEATLANDS AND THE DOMINANT PLANT-TYPE OF PEATLANDS: BRYOPHYTES (I.E. NON-VASCULAR PLANTS WITH NO ROOTS OR VASCULAR SYSTEMS).
 - SNOW, FROZEN SOIL & INTERPLAY WITH NON-FROZEN SOIL HYDRO-THERMAL PROCESSES